STATUS REPORT ON THE PERFORMANCE OF NEG-COATED CHAMBERS AT THE ESRF*

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Abstract

At the ESRF, the use of non-evaporable getter (NEG)-coated narrow gap chambers for insertion device (ID) straight sections (SS) has become the standard choice for in-air IDs. A total of 27 chambers have been installed at different times in the ring, with 20 being in place as of June 2006, for a total length of ~90 m. The vacuum performance has been excellent for all but one of them. It has been found that the now standard “10 mm” design, i.e. a 5 m-long, 57x8mm^2 ellipse, with a minimum wall thickness of 1 mm, is compatible with the multi-bunch operation at 200 mA. Runs at higher currents, performed in preparation of current upgrades, have gone smoothly. During 2005, a 3.5 m-long prototype of a chamber suited for installation in the achromat part of the lattice has been installed in the ring. It was characterized by a much smaller cross-section (30x20mm^2, elliptical, HxV) as compared to the present design chamber (74x33 mm^2, octagonal, HxV), and by the absence of 3 lumped pumping ports, replaced by the NEG-coating. The data taken during a full run have been extremely encouraging, to the point of considering the adoption of a similar design for a future upgrade of the storage ring magnetic lattice and vacuum system. A status report is given, alongside with a discussion of future plans.

HISTORICAL DEVELOPMENTS AND STATUS

Since March 2000 [1], the ESRF has been the first synchrotron radiation (SR) accelerator to implement on a large scale the emerging technology of NEG-coatings [2]. The first chambers were coated at CERN, while we were equipping ourselves with a NEG-coating facility [3]. All this has been done in parallel with the development of extruded-aluminium vacuum chambers, a technology which has a number of advantages over the previous one based on extensive use of electron-beam welding or brazing of stainless steel (SST) and copper parts. Spurred by an early paper claiming a large increase of the resistive-wall impedance (RWI) due to the NEG coating [4], the Machine Division of the ESRF has complemented our machine and vacuum measurements and data analysis by performing a number of machine-dedicated time (MDT) studies aiming at measuring the RWI of all ID SS, in order to determine the impact of future installations of NEG-coated chambers [5]. So far no show-stoppers have been found, and therefore the program of upgrading the remaining ID SS equipped with bigger vertical gaps is going on, at the ideal rate of one new chamber per machine shutdown (SD, 5 SD per year).

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The situation in the ring as of June 2006 is shown in Fig. 1.

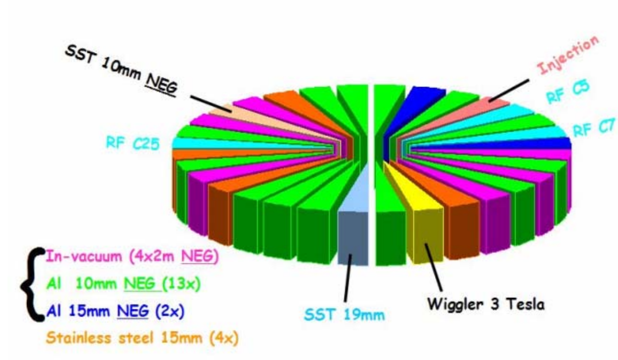

Figure 1: Straight section occupancy as of June 2006.

Among the 20 NEG-coated chambers in the ring there are 4 which are ~2m long, in the SS where single in-vacuum undulators are located. Of the remaining 16, one is the last of the first version of NEG-coated chambers (“10 mm” SST, with Cu coating), and 2 are made using the bigger “15 mm” version of 74x11 mm^2 elliptical cross-section, same as the 2 m-long ones.

VACUUM, BREMSSTRAHLUNG AND BEAMLOSS MEASUREMENTS

Measuring Set-up

All cells of the ESRF ring are equipped with a number of different beamloss detectors (ionization chambers and scintillators), which are used in conjunction with the pressure readouts in order to characterize the performance of all chambers in the ring. When a new chamber is NEG-coated in our facility, it is first installed on a dedicated SS, ID6, where it is fully characterized for an entire run (typically between 150 and 200 A·hours of integrated beam dose). Our Safety Group has equipped the experimental hutch of ID6 with a small ionization chamber centered on the axis of the SS [6], so as to intercept the primary bremsstrahlung (BS) radiation cone generated by the interaction of the stored electron beam with the residual gas along the SS and the parts of the machine on the same straight line-of-sight which preceed and follow the ID section. That means that the BS detector sees the interaction over ~15 m, where only about 5.8 m are taken by the ID chamber itself and by the two pumping manifolds at its extremities (equipped with bellows, beam-position monitors and vacuum gauges). Normally, at each SD only these 5.8 m are exposed to air, while the remaining part of the straight line-of-sight of the machine stays under vacuum thanks to all-metal gate valves. The vacuum conditioning of each ID chamber is then followed using two inverted-magnetron cold-cathode gauges (PEN1 and PEN3) installed at either pumping manifold chamber, above the 120 l/s StarCell® ion pumps. One residual-gas analyzer (RGA) is located on the downstream manifold chamber, in front of PEN3. One photon absorber is located on the UPS chamber, and none on the DWS chamber. At the end of an experimental run, depending on the behaviour of the chamber, the decision is taken concerning its fate. Either it is considered OK for the installation on an experimental beamline's (BL) SS, or it is rejected and removed from the storage ring (which has happened only once so far).

Conditioning Curves

Generally speaking, there are 4 different possibilities for a NEG-coated ID chamber in the machine, depending on wether it be installed on ID6 or on a BL SS. 1) New ID chamber with new upstream and downstream (UPS/DWS) pumping manifolds; 2) Pre-conditioned ID, UPS and DWS chambers; 3) New ID chamber with pre-conditioned UPS/DWSs; 4) One-run pre-conditioned ID chamber with multi-runs pre-conditioned UPS/DWS (e.g. after validating the ID chamber on ID6).

The vacuum conditioning curves for these 4 cases are shown in Fig. 2 and 3, PEN1 and PEN3 respectively, while Fig. 4 shows the BL signal conditioning measured by one scintillator detector placed in front of the crotch absorber of the first dipole of cell 6.

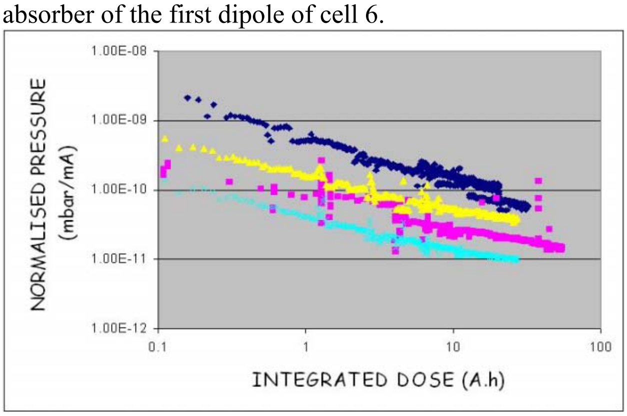

Figure 2: PEN1 conditioning plots. For these and the two following figures, case 1 is shown in blue symbols, case 2 is in pink, 3 in yellow, 4 in cyan.

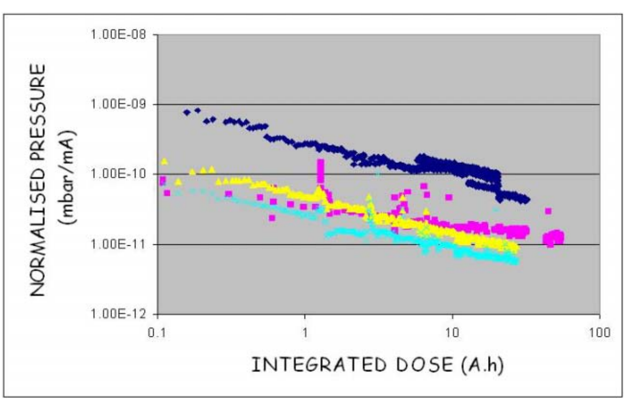

Figure 3: PEN3 conditioning plots.

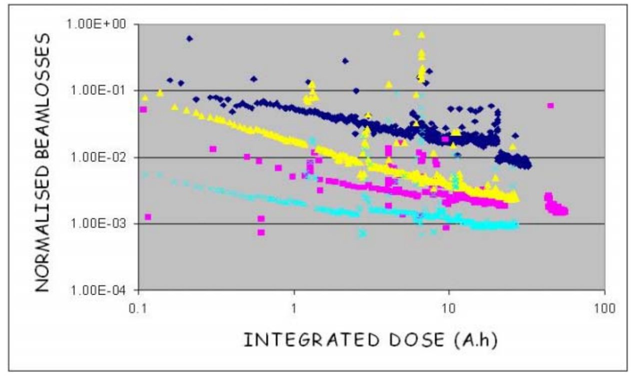

Figure 4: Beam-loss detector conditioning.

The benign effect of pre-conditioning is evident on all plots, and that makes the move of an ID chamber (eventually with ancillary UPS/DWS) to the final destination BL highly predictable in terms of radiation safety for BL personnel, who may otherwise be exposed to unwanted levels of BS radiation. So far, all ID chambers which have been pre-conditioned on ID6 and then moved to a final ID SS, have performed well. In one case, when occasional bursts of high-energy BS radiation had been measured by the BL ionization chambers on the experimental hutch, and which had erroneously been attributed to problems of adhesion of the NEG coating along the ID chamber, local venting and inspection of the area has led us to identifying the problem as being due to particle detachment from one adjacent vacuum component. Further inspection is due soon.

Prototype Quadrupolar Chamber

One of the possible machine upgrades foreseen by the long-term strategy of the ESRF is to re-design the magnetic lattice in order to obtain longer ID SSs, so as to be able to install canted undulators and therefore increase the number of experimental BL, with no need for major changes to the ESRF tunnel structure [7]. At the same time, new, more compact magnets could be installed, and making use of a smaller vacuum chamber would certainly become a major asset. With this in mind, we have started a program of development of compact, "pump-less" vacuum chambers [3], aiming at producing, coating and testing on the machine a 3.5 m-long chamber, characterized by a small cross-section (30x20 mm^2, elliptical, called herein "ESRF-2") as compared to the present ESRF standard design, as indicated in Fig. 5.

The tested chamber was 3.53 m-long, made out of extruded aluminium, and coated in our facility. The chamber was located immediately after the ID chamber in cell 6, in the so called CV3 location. This made it possible to follow its conditioning by using the Safety Group's BS detectors, as explained before. Fig. 6 shows the vacuum conditioning measured by the vacuum gauge PEN3 (entrance of the CV3), and by PEN4 (exit of the CV3). Fig. 7 shows the BLD signal conditioning of this chamber and compares it to an ID/UPS/DWS new set up installed immediately upstream of it (same as fig.4). By comparing to Fig. 3, it can be seen that the vacuum conditions indicated by PEN3 is marginally better than that of a complete new set ID/UPS/DWS, which is probably due to the bigger specific conductance of the ESRF-2 quadrupole chamber with respect to the ID chamber, about 1.7 l·m/s vs 0.92 l·m/s, respectively. Another reason for the lower pressures, is the fact that the total bending magnet photon flux impinging onto a CV3-type chamber is smaller than that of an ID chamber, as the distance from the source point is bigger.

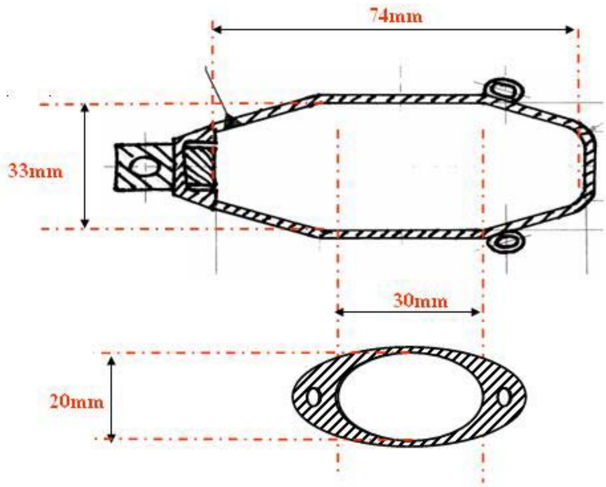

Figure 5: ESRF-1 vs ESRF-2 quadrupole cross-section.

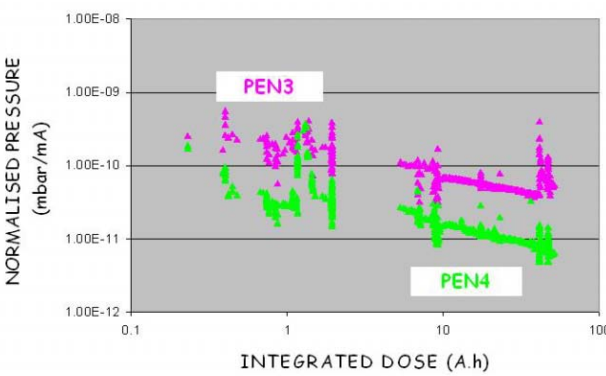

Figure 6: Vacuum conditioning plot for the new ESRF-2 chamber.

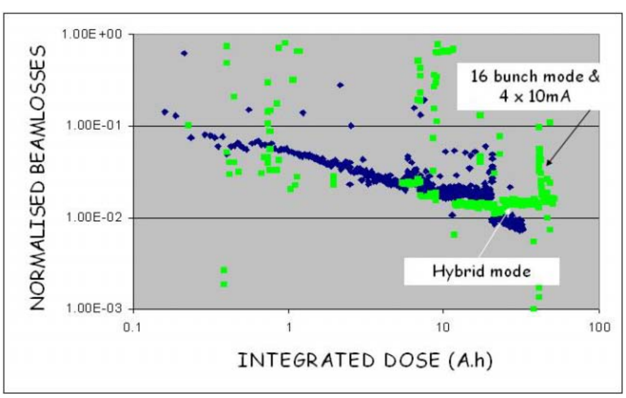

Figure 7: Beam-loss detector conditioning plot for the new ESRF-2 chamber.

For reference, the existing ESRF quadrupole cross-section, shown in Fig. 5, has a calculated specific conductance of 15.9 l·m/s. It is pumped by one 45 l/s ion-pump and two 200 l/s NEG pumps, by means of dedicated pumping ports going through the 3 quadrupole magnet yokes located along the chamber [7].

FUTURE PLANS

In the short term, and before the long-term strategy upgrade program is finalised, we plan to continue the installation of the "10 mm" NEG coated chambers on the BL SSs which are still equipped with bigger chambers. We are also working towards the improvement of the quality control of the NEG-coating process, and the characterization of the chambers on the machine, by means of dedicated MDT shifts, similar to what has been done in the past with calibrated leaks [9], when evidence that the NEG coating displays low SR-induced desorption yields even after complete saturation, as confirmed also in [10].

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